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Possibilities for Increasing the Antioxidant and Polyphenol Content of Strawberry Nectar (*Fragaria × ananassa*) by Adding Various Medicinal Herbs

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ABSTRACT

The objective of the present study was to determine the antioxidant and polyphenol content of strawberry nectars (*Fragaria* × *ananassa*) prepared with different herbs, and whether these contents remained constant or decreased over time. After strawberry processing, the prepared herbs were incorporated into the samples at concentrations of 1.0 and 2.0 m/m %. The results showed that the incorporation of 1 % lemon balm increased the antioxidant levels in the products by more than twofold (2.93 to 9.19 mg AAE mg/mL), while the addition of 2 % lemon balm led to a more than sixfold increase (2.93 to 17.16 mg AAE mg/mL) in the antioxidant content on the first day of measurement compared to the control samples. However, this level decreased by the end of the shelf life (Lg-1.0 to 3.06 mg AAE/mL; Lg-2.0 to 11.22 mg AAE/mL). Peppermint also increased antioxidant levels to 9.99 mg AAE/mL in the best case. However, antioxidant levels were found to decrease in response to ginger supplementation, with levels dropping to 1.90 mg AAE/mL. The sensory tests showed that in addition to the control product, the samples with 1 and 2 m/m % ginger (Gi) were the most popular among tasters.
Keywords: strawberry, peppermint, lemon balm, ginger, FRAP, Folin-Ciocalteu

1. INTRODUCTION

In recent years, the global prevalence of non-communicable diseases (NCDs) has become a significant public health concern. This is largely due to contemporary lifestyles characterised by high levels of processed food consumption, exposure to various chemical compounds and sedentary lifestyles (Budreviciute et al., 2020). Such lifestyles play an important role in triggering oxidative

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stress in humans (Sharifi-Rad et al., 2020). Enriching foods with phenolic compounds is becoming increasingly popular due to their beneficial physiological effects (Ziauddeen et al., 2019). However, analysing polyphenols in functional food matrices is difficult due to the matrices' complexity (Sik et al., 2022). While dietary polyphenols are not essential for humans, a growing body of research suggests that consuming polyphenol-rich foods and beverages, such as fruits, vegetables, cereals, tea, coffee, and wine, can have positive health benefits (Chew et al., 2019).

The strawberry (*Fragaria* x *ananassa Duch.*) belongs to the Rosaceae family and the Fragaria genus. Regarded as one of the most popular and widely cultivated berry fruits on the planet, it is often referred to as the 'queen of fruits' (Qin et al., 2008). Strawberry phytochemicals are mainly represented by a large class of phenolic compounds that perform many non-essential functions in plants and exhibit significant biological potential in humans (Häkkinen & Törrönen, 2000). The phenolic compounds found in strawberries include anthocyanins, which are responsible for the berries' bright red colour (Mustafa et al., 2022). Notably, strawberries also contain other valuable groups of phenolic compounds, including hydrolysable tannins (i.e., ellagitannins). Smaller concentrations of phenolic compounds are also present, including flavonols, hydroxycinnamic acid esters (especially p-coumaric acid esters) and ellagic acid glycosides (Buendía et al., 2010).

In recent years, much emphasis has been placed on identifying the functional constituents of lemon balm (*Melissa* x *officinalis*). Studies have shown that lemon balm has a high concentration of phenolic compounds, including phenolic acids, flavonoids, and condensed tannins. Mono- and polymeric flavonoids such as luteolin and apigenin glycosides, as well as proanthocyanidins, have been shown to contribute significantly to the antioxidant and anti-inflammatory properties of lemon balm essential oil-free extract (Francisco et al., 2013). Flavonoids such as luteolin, which are abundant in lemon balm, exhibit a variety of biological activities, including antioxidant, antimicrobial, anticancer, antiallergic, and anti-inflammatory properties (López-Lázaro, 2009).

Peppermint (*Mentha* x *piperita*), which originates from Europe, is another example of such a cross, most likely occurring in ancient times. Today, it is established worldwide (Simmonds et al., 2017). Similar to lemon balm, peppermint contains high concentrations of phenolic compounds (Székelyhidi et al., 2022). Peppermint's polyphenol composition involves around 40 compounds, 53 % of which are flavonoids, followed by phenolic acids (42 %), lignans (2.5 %), and stilbenes (2.5 %). Mint leaves are commonly used in cooking, and consuming them can contribute to the redox balance of human cells as they contain phytochemicals such as vitamins, phenolic compounds, and terpene antioxidants (Brown et al., 2019).

Like the previous two herbs, common ginger (Zingiber officinale Roscoe) contains high concentrations of bioactive components that help bind free radicals and reactive oxygen. The main active components of fresh ginger are zingerone, gingerol, shogaol, and paradol (Mohammad et al., 2021). Ginger has been shown to treat and inhibit many conditions, including inflammation, platelet aggregation, nausea, vomiting, high blood pressure, cardiovascular disease, oxidative damage, diabetes, colds, asthma, allergies, migraines, and some cancers (Faddaddeen, 2022; Mao et al., 2019).

The idea for this research came from the widespread consumption of commercially available nectars, produced from various fruits. These nectars are often made from red fruits, which are recognised for their high antioxidant content. However, the variability of their quantity within the products remains to be elucidated. This study aimed to investigate whether the amount of antioxidants and polyphenols in our product remains constant or decreases over time.

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2. MATERIALS AND METHODS

The 7 kg of raw material (*Fragaria* × *ananassa*) used in the experiment was sourced from a fully ripe batch grown by a Hungarian organic gardening unit (Five Farm, Rajka). The fruit was harvested on 5 July 2021. The degree of maturity was determined using a density meter (Rudolph DDM 2910), which indicated a sugar content of 9° Brix (a relatively low sugar content). Commercially purchased dried herbs were used for the experiments. Contamination of the self-grown herbs would have been critical to our experiments, so materials were sourced from a distributor (Herbária Ltd.) that operates under ISO, GMP and HACCP quality management systems (Hungary). Any plant parts that were not fit for consumption and any unripe fruits were discarded immediately upon arrival of the materials, after which preparation began. The strawberry to be tested was crushed using a hand blender (Bosch). Weight measurement was performed using an APX-3202 precision storage scale (Denver Instrument) and a TE214S analytical balance (Sartorius). During the testing period, the product was pasteurised using an electric hotplate, and the strawberry nectar was stored in an air-conditioned cabinet. Centrifugation was performed using a Hermle Z206A centrifuge, and measurements were taken using a Pharo 100 spectrophotometer (Merck). The following reagents were used for the experiments: Folin-Ciocalteu reagent (Merck), anhydrous sodium carbonate (Riedel de Haën), gallic acid (Sigma-Aldrich), sodium acetate (Merck), TPTZ (Sigma-Aldrich), anhydrous ferric chloride (Merck), ascorbic acid (Sigma-Aldrich), acetic acid (Reanal), and high-purity water. The analytical laboratory produces high-purity water for tests and other additional operations with Zeneer Power 1 type water purification equipment (Human Corporations).

2.1 Technology process

The strawberries were processed by having their stems removed, being washed thoroughly with tap water, and being chopped using a hand blender. The fresh ginger used as an additive was peeled and grated by hand, while the dried lemon balm and peppermint were sorted and the stem pieces removed. After chopping the strawberries, 500 mL of purée was measured in a beaker using scales and diluted with 500 mL of water. To create a pleasant taste and extend the shelf life, 1.5 g of sodium benzoate and 45 g of sucrose were added to the mixture. Peppermint, lemon balm and ground ginger were then added to the prepared nectars at concentrations of 1 % and 2 % (m/m). The strawberry nectar was then heat-treated at 85 °C for 25 minutes using an electric hotplate. The nectar was then transferred to previously sterilised brown bottles, which were sealed with lids. Heat treatment was necessary to ensure the nectar's shelf life. Although other research has shown that heat treatment reduces the amount of bioactive compounds in the product (Alim et al., 2023), microbial infection would cause greater damage during storage. The nectars were then cooled to 35 °C in a cold-water bath (25 °C). The seven different strawberry nectar compositions were stored at 22 °C for six weeks in an air-conditioned cabinet, protected from light. The fruit nectars were sampled every two weeks (on days 1, 11, 28 and 42). Approximately 40 mL of strawberry nectar was measured into a 50 mL sterile centrifuge tube and stored in an ultra-deep freezer (CHEST ULT -86 °C, Fisher Scientific) at -55 °C until further analysis.

The nectars were then supplemented with ground peppermint, lemon balm, and ginger at concentrations of 1 % and 2 % by weight (m/m), as follows:

- *C [Control sample]:* 500 g fruit puree + 500 g water + 1.5 g sodium benzoate + 45 g sucrose
- *Pm-1.0 [Peppermint 1 %]:* 471.75 g fruit puree + 471.75 g water + 10 g peppermint + 1.5 g sodium benzoate + 45 g sucrose

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- *Pm-2.0 [Peppermint 2 %]:* 466.75 g fruit puree + 466.75 g water + 20 g peppermint + 1.5 g sodium benzoate + 45 g sucrose
- *Lg-1.0 [Lemon balm 1 %]:* 471.75 g fruit puree + 471.75 g water + 10 g lemon balm + 1.5 g sodium benzoate + 45 g sucrose
- *Lg-2.0 [Lemon balm 2 %]:* 466.75 g fruit puree + 466.75 g water + 20 g lemon balm + 1.5 g sodium benzoate + 45 g sucrose
- *Gg-1.0 [Ginger 1 %]:* 471.75 g fruit puree + 471.75 g water + 10 g ginger + 1.5 g sodium benzoate + 45 g sucrose
- *Gg-2.0 [Ginger 2 %]:* 466.75 g fruit puree + 466.75 g water + 20 g ginger + 1.5 g sodium benzoate + 45 g sucrose

The 1 % and 2 % aqueous solutions of medicinal lemon balm, peppermint and ordinary ginger that were used in the experiment were also tested. Samples of each herbal aqueous extract were taken on the first and last days of the shelf-life test (days 1 and 42).

2.2 Determination of total polyphenol content

The total polyphenol content (TPC) of the extracts was measured using the Folin-Ciocalteu method (Barba et al., 2013; Singleton et al., 1999), with slight modifications. After preparing the stock solutions, the strawberry nectar samples and aqueous solutions were centrifuged at 6000 rpm for 20 minutes. Then, 1.5 mL of high-purity water was pipetted into 50 µl of the supernatant in the centrifuged samples, followed by the reagents (2.5 mL Folin reagent and 2 mL Na_2CO_3). The absorbance was measured at 725 nm versus the blank after 90 minutes of incubation at room temperature. TPCs were expressed as milligrams of gallic acid equivalents per gram of dry plant material (mg GAE/g). After 90 minutes of incubation, the absorbance of the samples at a wavelength of 750 nm was measured.

2.3 Determination of total antioxidant content

The antioxidant content of the samples was measured using the FRAP method, which is based on electron transitions. Absorbance can be measured at 593 nm after five minutes using a spectrophotometer (Benzie & Strain, 1996). L-ascorbic acid was used in the test, so the antioxidant capacity of the samples was expressed in relation to ascorbic acid (mg of ascorbic acid equivalents/mL). First, the stock solutions required for the tests (FRAP solution, acetate buffer, TPTZ solution, and iron chloride solution) were prepared. The samples were then centrifuged at 6000 rpm for 20 minutes to determine the total polyphenol content. Then, 3 mL of FRAP solution and 100 µl of distilled water were added to the 50 µl of supernatant extracted from the strawberry nectar and aqueous solutions. The absorbance was detected after five minutes at a wavelength of 593 nm.

2.4 Sensory evaluation

The organoleptic evaluation of the fortified and control nectars was conducted by the Department of Food Science at Széchenyi István University immediately following production. The testers were 15 individuals aged between 19 and 55. Participants were asked to rate key aspects of the nectars (colour, smell, taste, flavour and overall acceptability) on a 9-point hedonic scale, where 1 signified strong disapproval and 9 strong approval (Wichchukit & O'Mahony, 2015). The nectars were served in white cups and distinguished by alphabetical markers.

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2.5 Data analysis, statistical methods

The results obtained using the Microsoft Office Excel (2016) programme were evaluated during the experiment. The data were expressed as the mean (n = 3) ± relative standard deviation (RSD). One-way analysis of variance (ANOVA) was used to identify significant differences in the data. Values were considered significant at $P \leq 0.05$. Significant differences in individual figures marked with the letters 'a-b-c-d' were identified.

3. RESULTS AND DISCUSSION

3.1 Antioxidant

Table 1 shows the antioxidant results for the raw material and the diluted nectar, both before and after heat treatment. It also shows the data for the aqueous solution of sodium benzoate and sugar. The antioxidant content of the raw strawberries prior to dilution (RM) was 3.95 mg AAE/mL. The amount of valuable compounds in the fruit diluted with water at a ratio of 1:1 (DN-BH) was 2.51 mg AAE/mL, increasing to 5.72 mg AAE/mL as a result of heat treatment (DN-AH). Previous research has confirmed that the amount of phenolic compounds in many plants is increased by heat treatment (Bodor et al., 2021; Chumyam et al., 2013; Kim et al., 2006). The heat treatment process for plant raw materials (mainly boiling the nectar) and the cracks in the cell walls caused by the heat can also affect the extractability of (poly)phenols (Harris et al., 2015; Palermo et al., 2014). Applying heat during the technological process increased the concentration of these compounds. This phenomenon can be attributed to the exposure of fruit cells during heat treatment, which leads to the release of compounds from these cells (Jeong et al., 2004; Kim et al., 2006; Y. Li et al., 2022). It is important to emphasise that an aqueous solution of sodium benzoate and sugar was also tested, and the total antioxidant content was found to be 0 mg AAE/mL. Therefore, it can be concluded that these compounds did not interfere with the measurements. However, it is also important to emphasise that high doses of sodium benzoate can lead to oxidative stress. Some research has shown that it increases oxidative damage in the human body and affects sodium and potassium levels (Khan et al., 2022; Olofinnade et al., 2021).

Table 1: Results of the TA content of samples (RM – raw material; DN-BH – Diluted nectar before heat treatment; DN-AH – Diluted nectar after heat treatment; SB-S – Sodium-Benzoate + Sugar)

Sample	TA content mg AAE/mL*
RM	3.95 ± 0.05
DN-BH	2.51 ± 0.05
DN-AH	5.72 ± 0.01
SB-S	0.00

* Values are means ± SE (n = 3).

Figure 1 shows the results measured during the 42-day storage of the prepared control and herbal products. For the control samples (C), the total antioxidant concentration was highest on the first sampling day at 2.93 mg AAE/mL. However, this decreased significantly to 2.12 mg AAE/mL by the 14th day (C14) (see *Figure 1*). The amount of these compounds in the control samples did not appreciably change during the tested shelf life. Based on these results, it can be concluded that adding peppermint and lemon balm significantly increased the amount of antioxidant compounds at both dosing concentrations ($P \leq 0.05$). This significant difference was evident throughout the

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storage period (42 days). However, in contrast to samples supplemented with lemon balm and mint, the amount of beneficial compounds in the ginger samples decreased. This tendency was also observed in comparison to the control samples. This can be attributed to the pro-oxidant effect of ginger compounds, which has been confirmed by previous research under certain conditions (Annamalai et al., 2016). Previous studies have reported that the α,β-unsaturated carbonyl group present in [6]-shogaol exhibits growth-inhibitory and cytotoxic properties. Thus, the pro-oxidant effect of [6]-shogaol can induce the formation of free radicals (Fulda, 2010; Gan et al., 2011). Statistical analysis shows that there is no significant difference between the control samples and the Pm-1.0 (P-value = 0.13) and Pm-2.0 (P-value = 0.20) samples. However, the C samples and the Lg-2.0 samples show a significant difference (P-value = 0.0003).

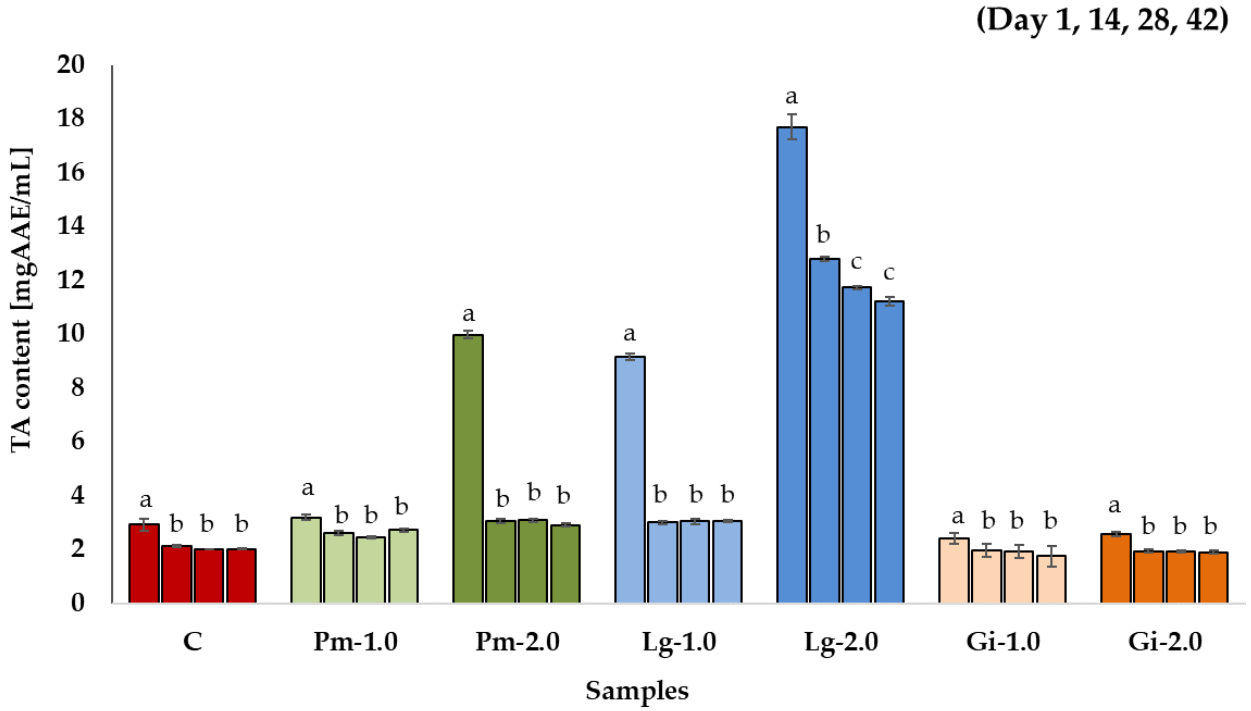

Figure 1: Results of the TA content of samples during storage period (C - Control sample; Pm-1.0 - Sample with added 1.0 % (m/m) peppermint; Lg-1.0 - Sample with added 1.0 % (m/m) lemon balm; Gi-1.0 - Sample with added 1.0 % (m/m) ginger; Pm-2.0 - Sample with added 2.0 % (m/m) peppermint; Lg-2.0 - Sample with added 2.0 % (m/m) lemon balm; Gi-2.0 - Sample with added 2.0 % (m/m) ginger)

The 1 % and 2 % herbal aqueous solutions were also tested, with the results presented in *Table 2.* No significant changes occurred in the extracts containing 1 % medicinal herbs until the end of the shelf life (see *Table 2*). The quantity of antioxidants in the ginger samples was negligible at both concentrations. Conversely, the samples containing 2 % medicinal herbs exhibited substantially higher levels of antioxidant compounds. However, these beneficial components decreased significantly by the end of the storage period. The aqueous extracts containing 2 % lemon balm exhibited the greatest increase in valuable compounds, reaching concentrations of 2.35 mg AAE/mL and 1.87 mg AAE/mL respectively. A similar trend was observed in the 2 % mint solution, with elevated antioxidant levels detected on the initial sampling day for this herb.

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Table 2: Results of the TA content of water based samples at the beginning and end of the storage period (C - Control sample; Pm-1.0 - Sample with added 1.0 % (m/m) peppermint; Lg-1.0 - Sample with added 1.0 % (m/m) lemon balm; Gi-1.0 - Sample with added 1.0 % (m/m) ginger; Pm-2.0 - Sample with added 2.0 % (m/m) peppermint; Lg-2.0 - Sample with added 2.0 % (m/m) lemon balm; Gi-2.0 - Sample with added 2.0 % (m/m) ginger)

Sample	TA content mg AAE/ mL*	
	Day 1	Day 42
Pm-W 1 %	0.56 ± 0.08[a]	0.51 ± 0.04[a]
Pm-W 2 %	1.42 ± 0.11[a]	1.10 ± 0.03[b]
Lg-W 1 %	1.01 ± 0.10[a]	0.95 ± 0.02[a]
Lg-W 2 %	2.35 ± 0.10[a]	1.87 ± 0.04[b]
Gi-W 1 %	0.05 ± 0.01[a]	0.03 ± 0.00[b]
Gi-W 2 %	0.08 ± 0.00[a]	0.06 ± 0.01[b]

* Values are means ± SE (n = 3). Within each line, values with different letters are significantly different ($P < 0.05$).

3.2 Polyphenol

Table 3 shows the total phenolic content (TP) results for the raw material, the diluted nectar before and after heat treatment, and the aqueous solution of sodium benzoate and sugar. The polyphenol content of the prepared raw strawberry (RM) was 0.95 mg GAE/mL; after dilution with water (DN-BH), it was 0.87 mg GAE/mL (see *Table 3*). Other studies have shown that strawberries contain between 1.47 and 2.87 mg GAE/g of such compounds (Koyama et al., 2022). However, other studies have found this value to be between 0.99 and 1.58 mg GAE/g (Ürün et al., 2021). The antioxidant and polyphenol content of fruits depends on their state of maturity and time of harvest (Jaakola & Hohtola, 2010; Palmieri et al., 2017). However, it has also been proven that the amount of these compounds is influenced by post-harvest treatments such as storage temperature and duration (Koyama et al., 2022). By way of comparison, the polyphenol content of the diluted nectar (DN-AH) was 1.25 mg GAE/mL after heat treatment (*Table 3*). Previous research has shown that the polyphenol concentration of strawberry products can increase as a result of heat treatment (Holzwarth et al., 2012). It is important to note that an aqueous solution of sodium benzoate and sugar (SB-S) was also tested, with the total polyphenol content being determined to be 0 mg GAE/mL.

Table 3: Results of the TP content of samples during fermentation process (RM – raw material; DN-BH – Diluted nectar before heat treatment; DN-AH – Diluted nectar after heat treatment; SB-S – Sodium-Benzoate + Sugar)

Sample	TP content mg GAE/ mL*
RM	0.95 ± 0.04
DN-BH	0.87 ± 0.05
DN-AH	1.25 ± 0.03
SB-S	0.00

* Values are means ± SE (n = 3).

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Figure 2 shows the TA results measured during the 42-day storage of the prepared control and herbal products. Previous studies have investigated the phenolic compounds of lemon balm (Aboagye et al., 2021; Elchaghaby et al., 2022), peppermint (Mahdavikia et al., 2017) and ginger (Özcan, 2022). For the control samples devoid of medicinal plants, the polyphenol content was 1.15 mg GAE/mL on the first sampling day (C1) (see *Figure 2*). As the shelf life progressed, a decrease in the amount of valuable compounds was observed; however, no significant difference was detected between the first and last sampling days. The total polyphenol content (C42) decreased to 0.96 mg GAE/mL. Juices containing 2 % lemon balm exhibited the highest total polyphenol content, with a reading of 1.95 mg GAE/mL recorded on the initial sampling day (Lg-1.0). However, a significant decrease in polyphenol content was observed on the 14th sampling day, with a 16 % decrease in content by the end of the tested shelf life. In the case of strawberry nectars containing 1 % peppermint (Pm-1.0), a significant decrease was observed between the first and second/third samples. A substantial 19 % decrease in polyphenol content was observed at the end of the shelf-life study compared to the initial reading. Conversely, no significant changes were observed in samples containing 1 % common ginger (Gi-1.0) during the shelf-life test. The highest concentrations of valuable compounds were observed in nectars containing 2 % lemon balm (Lg-2.0). On the first sampling day (C1), the polyphenol content was 1.95 mg GAE/mL, significantly decreasing to 1.77 mg GAE/mL by the 14th day. On the 28th day, the components were present in similar amounts (1.76 mg GAE/mL), but by the end of the storage period, the total polyphenol content had decreased significantly to 1.63 mg GAE/mL. For the sample containing 2 % peppermint (Pm-2.0), the change in polyphenol concentration was similar, resulting in the highest total antioxidant content on the first sampling day (1.52 mg GAE/mL). Subsequently, a significant decrease occurred at the end of the storage period. For the common ginger sample (Gi-2.0), the polyphenol content at this concentration was lower than that of the control samples (C). This finding is consistent with previous studies reporting a decline in phenolic compounds over time (Oliveira et al., 2014).

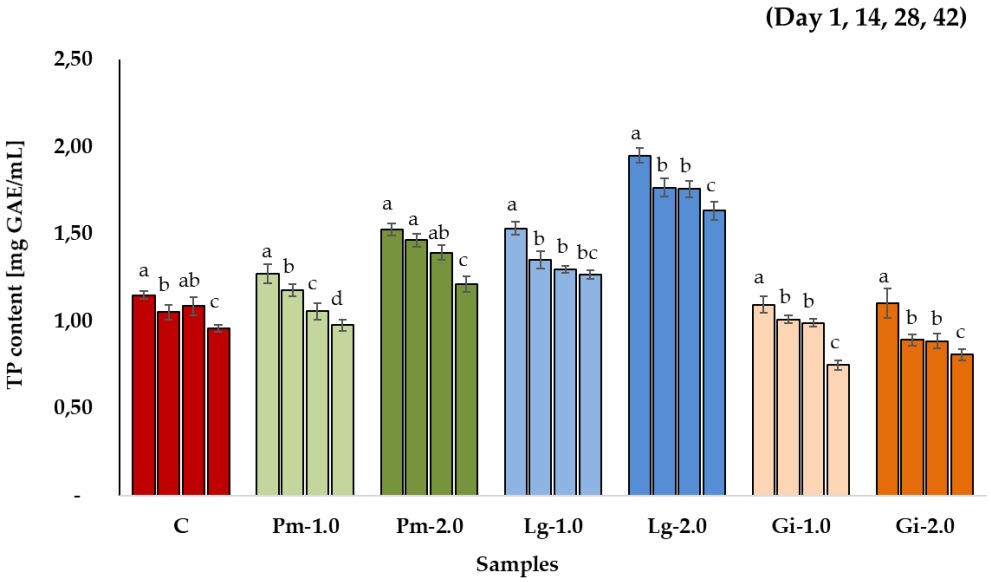

Figure 2: Results of the TP content of samples during storage period (C - Control sample; Pm-1.0 - Sample with added 1.0 % (m/m) peppermint; Lg-1.0 - Sample with added 1.0 % (m/m) lemon balm; Gi-1.0 - Sample with added 1.0 % (m/m) ginger; Pm-2.0 - Sample with added 2.0 % (m/m) peppermint; Lg-2.0 - Sample with added 2.0 % (m/m) lemon balm; Gi-2.0 - Sample with added 2.0 % (m/m) ginger)

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Table 4 shows that the concentration of valuable compounds in the 1 % herbal extracts is lower than in their 2 % counterparts, with the exception of ginger extract. In the case of this medicinal plant, neither the 1 % nor the 2 % sample increased the total polyphenol concentration.

Table 4: Results of the TP content of water based samples at the beginning and end of the storage period (Pm-W 1 % - Sample with added 1.0 % (m/m) peppermint; Lg-W 1 % - Sample with added 1.0 % (m/m) lemon balm; Gi-W 1 % - Sample with added 1.0 % (m/m) ginger; Pm-W 2 % - Sample with added 2.0 % (m/m) peppermint; Lg-W 2 % - Sample with added 2.0 % (m/m) lemon balm; Gi-W 2 % - Sample with added 2.0 % (m/m) ginger)

Sample	TP content mg GAE/ mL*	
	Day 1	Day 42
Pm-W 1%	0.56 ± 0.08[a]	0.51 ± 0.04[a]
Pm-W 2%	1.42 ± 0.11[a]	1.10 ± 0.03[b]
Lg-W 1%	1.01 ± 0.10[a]	0.95 ± 0.02[a]
Lg-W 2%	2.35 ± 0.10[a]	1.87 ± 0.04[b]
Gi-W 1%	0.05 ± 0.01[a]	0.03 ± 0.00[b]
Gi-W 2%	0.08 ± 0.00[a]	0.06 ± 0.01[b]

* Values are given as means ± SE (n = 3). Within each line, values with different letters are significantly different ($P < 0.05$).

Among the aqueous extracts, the concentration of total polyphenols was highest on the first sampling day, including in the 2 % mint solution at 0.74 mg GAE/mL. However, by the end of the shelf life, the concentration of valuable compounds had decreased significantly to 0.38 mg GAE/mL. No significant differences emerged for the other herbs during the tested shelf life.
The results prove that the strawberries used to make the product contain significant amounts of beneficial antioxidants and polyphenols. The amount of these compounds increased as a result of the heat treatment applied during the production process. This can probably be explained by the exposure of the fruit's cells during the heat treatment and the effect of the compounds released from them.

3.3 Organoleptic Evaluation

As shown in *Figure 3*, the results of the sensory tests indicate that the samples containing 1 m/m % and 2 m/m % ginger (Gi) were the most popular with the tasters, in addition to the control product. This is probably due to ginger's long-standing popularity in medicine and gastronomy and its pleasant taste (Spence, 2023).
The addition of lemon balm to fruit nectars was considered the least attractive. Even a sample containing 2 % lemon balm (Lg) showed a significant difference (P-value = 0.0003) compared to the control sample.

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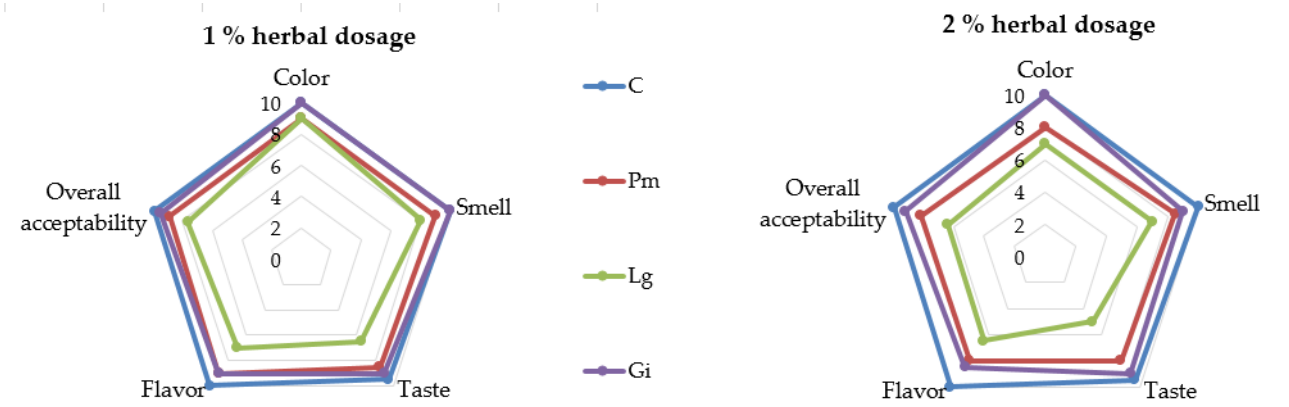

Figure 3: Results of the sensory properties of samples after the manufacturing process

4. CONCLUSIONS

The results prove that the strawberries used to make the product contain significant amounts of beneficial antioxidants and polyphenols. The amount of these compounds increased as a result of the heat treatment applied during the production process. This can be explained by the exposure of the fruit cells during the treatment and the effect of the released compounds. The research provides a comprehensive overview of the antioxidant and polyphenol content of all herbal strawberry nectars. Therefore, it can also be concluded that peppermint and lemon balm contain these beneficial compounds, and that the dosage concentration affects their appearance in the product. Based on shelf-life tests conducted over 42 days, it can be concluded that the levels of antioxidants and polyphenols are highest on the first day of testing, after which they decrease over time. The measurement results obtained demonstrate that the ginger plant decreases the amount of these valuable compounds rather than increasing it. Consequently, it was determined that ginger does not possess an antioxidant effect within the specified food matrix; thus, its incorporation into nectars is not advised. Overall, a 1 % dosage of lemon balm and peppermint has a beneficial effect on the antioxidant and polyphenol content of the product, meaning that consuming the prepared products can have a positive impact on health.

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Szamócanektár (*Fragaria* × *ananassa*) antioxidáns és polifenoltartalom növelésének lehetőségei különböző gyógynövények hozzáadásával

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ÖSSZEFOGLALÁS

A kutatás célja annak vizsgálata volt, hogy a különböző gyógy- és fűszernövényekkel (borsmenta, citromfű, gyömbér) adalékolt szamócanektárok (*Fragaria* × *ananassa*) antioxidáns- és polifenoltartalma állandó vagy csökkenő tendenciát mutat az eltarthatósági idő előrehaladtával. Az eper feldolgozása után az előkészített fűszernövényeket 1,0 és 2,0 m/m %-os koncentrációban adtuk a mintákhoz. A kísérletek során a citromfű 1 %-os adagolása több mint kétszeresére (2.93-9.19 mg AAE mg/mL), 2 %-os hozzáadott mennyisége pedig több mint hatszorosára növelte a termékekben lévő antioxidánsok mennyiségét (2.93-17.16 mg AAE mg/mL) a mérés első napján a kontroll mintákkal összehasonlítva. A jótékony hatású vegyületek koncentrációja azonban az eltarthatósági idő végére (42. nap) csökkent. A borsmenta adagolása a legjobb esetben 9.99 mg AAE/mL-re növelte az antioxidánsok mennyiségét is. A gyömbér hozzáadása azonban nem növelte, hanem inkább mérsékelte a hasznos vegyületek koncentrációját az általunk vizsgált mintamátrixban (1.90 mg AAE/mL). Az érzékszervi vizsgálatok pedig azt mutatják, hogy a kontrollterméken kívül az 1 és 2 m/m %-os gyömbérrel kiegészített minták nyerték el leginkább a kóstolók tetszését.

Kulcsszavak: szamóca, borsmenta, citromfű, gyömbér, FRAP, Folin-Ciocalteu

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